

EMERGENCE AND SURVIVAL OF *NASSELLA PULCHRA* IN A CALIFORNIA GRASSLAND

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ABSTRACT

We tested the hypothesis that prescribed burning and intense, short-duration grazing of the California annual grassland by sheep would increase emergence and survival of perennial bunchgrass seedlings at the Jepson Prairie Preserve in Solano County, California. Seeds of *Nassella (Stipa) pulchra* (Hitche.) Barkworth, either from a bulk seed collection or in three weight classes, were planted along paired transects on two topographic locations with differing soil depth. Treatment combinations that included burning or spring grazing produced higher rates of emergence than other treatments, but only in the first season after the burn. Very few seedlings (0.01%) survived in any treatment to the end of the fourth growing season. Although burning, grazing, and topography influenced the emergence of seedlings, survival to a mature stage appeared to be more strongly influenced by factors not manipulated or monitored in this study. Based on these data, we suggest that recruitment into the *N. pulchra* population may be strongly influenced by climatic variables and that the effectiveness of management techniques may be dependent on annual climatic variation. Management techniques for increasing *N. pulchra* populations must account for numerous and potentially specific habitat requirements of seedlings.

Heavy grazing by domestic animals and the introduction of invasive annual plants have been important factors in shifting community composition and dominance of California grasslands from native perennial grasses to exotic, annual grass and forb species in the last 200 years (Mack 1989). Native bunchgrasses, such as *Nassella pulchra*, tolerate light to moderate, seasonal defoliation from grazing (Painter 1995), but cannot withstand the impact of continuous defoliation by domestic livestock (Burcham 1957; Heady et al. 1992). The shift in the intensity of herbivory in the past two centuries, coupled with prolonged episodes of drought, allowed many exotic annual species to invade and dominate the California grassland in a remarkably short period of time (Burcham 1957; Mack 1989).

Experimental removal of grazing pressure has not resulted in either the return of native perennial grasses in inland California (Bartolome and Gemmill 1981; Baker 1989) or in elimination of introduced species (Biswell 1956; White 1967). The persistence of introduced annual species reflects the profound change in community

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structure that has occurred since European settlement. The rapid biomass production, dense canopy, and litter accumulation by annual species can modify many microhabitat characteristics of the grassland (Facelli and Pickett 1991). The quality of light reaching the base of perennial grasses can affect tillering rates (Derigibus et al. 1985), rate of phenological development (Weaver and Rowland 1952) and mortality of seedlings (Bartolome and Gemmill 1981). Litter accumulation can suppress grass seedling establishment by reducing temperature and humidity fluctuations that can be as important as light stimuli in controlling seed germination (Weaver and Rowland 1952; Knapp and Seastedt 1986).

Wildfire has also played an important role in grassland systems (Daubenmire 1968; Heady et al. 1992), but its influence may have been one of modifying rather than structuring the grassland community (Vogl 1974; Heady 1988). Little fire research has been done on perennial grasses in the annual-dominated system of California (Menke 1989). In the past, periodic fire helped maintain the vigor of the grassland, especially of bunchgrasses, by completely and indiscriminately removing the accumulation of litter and senescent biomass (Daubenmire 1968; Vogl 1974). Bunchgrasses experience early, vigorous regrowth and increased tillering in the growing season following a fire (Vogl 1974; Heady 1988). Resultant changes in soil temperature, soil water availability, and light penetration (Harvey 1949; Weaver and Rowland 1952; Cook 1979; Knapp and Seastedt 1986) have been implicated as important variables increasing growth and recruitment of perennial grasses.

The large seed bank and the tendency of introduced annual grasses to dominate a site can be manipulated through controlled burning, grazing, or both although the effects of such management is generally short-lived (Harvey 1949; Parsons and Stohlgren 1989). Studies have indicated a positive effect of grazing and of burning on perennial seedling establishment and survival by reducing the competitive effects of annual species (Bakker et al. 1980). Similarly, detrimental effects of competing species on seedling growth and survival have been reported (Ross and Harper 1972; Facelli and Pickett 1991).

The return of the California grassland to a perennial-grass dominated system would be desirable for improving range quality (Menke 1992), general habitat quality (Vogl 1974), and has potential for reducing the fire hazard created by annual grass litter. We hypothesize that management techniques for reducing aboveground biomass in spring and accumulated litter in summer such as controlled sheep grazing and prescribed fire will increase emergence and survival of *N. pulchra*.

MATERIALS AND METHODS

Site description. This study was conducted at the Jepson Prairie Preserve in Solano County, California, an inland grassland that is jointly managed by the University of California, Davis and The Nature Conservancy. The area is characterized by a mound and intermound topography underlain by an impervious clay layer at a depth of about 20 cm in intermound areas and of about 65 cm under mounds. The underlying clay creates a perched water table during the winter and spring months that results in a seasonally-wet, vernal pool environment in the intermound areas (Holland and Jain 1988). The soil at the preserve is classified as San Ysidro sandy loam (fine, montmorillonitic, thermic, Typic Palexeralfs).

The Mediterranean weather patterns of California's Central Valley produce long, hot, dry summers with the majority of the annual precipitation occurring in the cool, temperate winters. Annual rainfall was recorded at Davis, CA, 25 km northeast of the Jepson Prairie.

Present distribution of *N. pulchra* within the vernal pool habitat at Jepson Prairie is spatially variable. Typically, mature *N. pulchra* occur in higher numbers on top and on the slopes of mound areas with fewer occurring in the intermound areas and virtually none in the vernal pools proper. Contrasts between mounds and vernal pools include amount of vegetative cover (<30 percent vs. 100 percent), percent of native versus alien species (>70 percent vs. as low as 0 percent), and percent of alien annual species (<7 percent vs. up to 100 percent) (Holland and Jain 1988).

In December 1987, three experimental blocks of six contiguous 20-m by 20-m paddocks were established containing mature *N. pulchra* plants at densities we considered representative of the area (Fig. 1) and which contained similar amounts of mound and intermound areas. Six treatment combinations in a full factorial design of two levels of burning (burned or unburned) by three levels of grazing (spring or wet-grazed, summer or dry-grazed, and ungrazed) were randomly assigned to paddocks within each block. Seeding experiments were conducted using *N. pulchra* seed collected at the site in May 1988.

Each grazed paddock was stocked with 15 dry ewes for one short, intensive period (2–3 days) annually in March–April (wet-grazed) or in August (dry-grazed) from 1988–1992. The duration of grazing was manipulated to achieve a mean residual dry matter level of about 400–500 kg ha⁻¹ in the paddocks. Prescribed burns were applied in September of 1988 and 1991 when the senescent and dead aboveground biomass was completely dry.

In Experiment 1, four 2.5-m transects, two each in mound and intermound locations, were established in each paddock (Fig. 1).

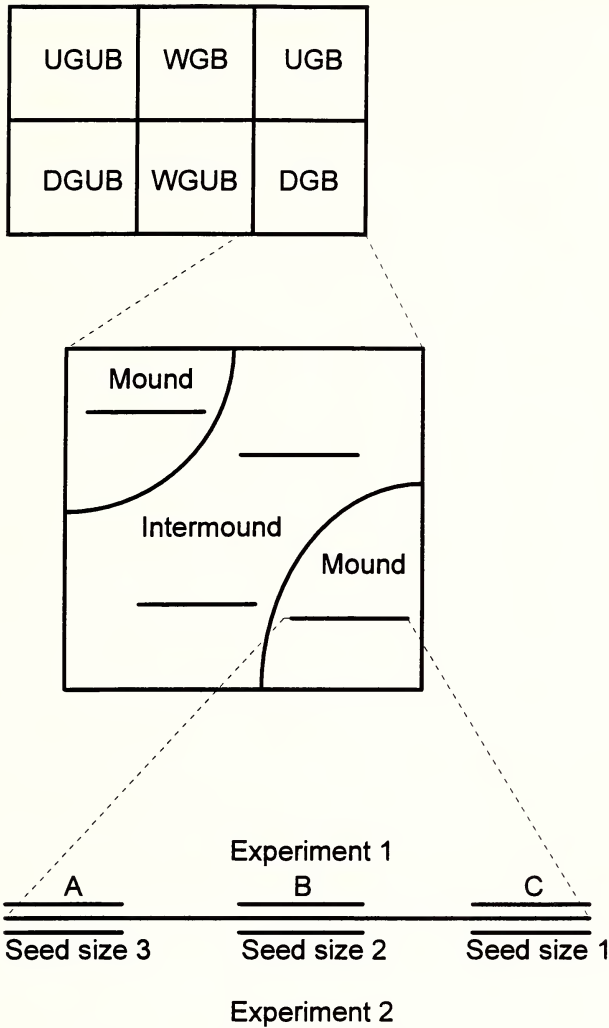


FIG. 1. Design of experimental plots with detail shown of representative blocks (top), paddocks (middle), and transects (bottom). Treatments are ungrazed (UG), wet-grazed (WG), dry-grazed (DG) and burned (B) or unburned (UB). Experiment 1 (1988) plots were located on the side of the transect closest to the center of the paddock. Sets of 20-point plots were planted on one side of the transect from left to right. Experiment 2 (1989) seeds were planted in 20-point plots according to seed size.

Each transect was permanently marked with nails and divided into three sections of 20 sample points (60 points per transect, 720 points per treatment in three replicated blocks). A 20-point wire frame (2.5 cm between points) was temporarily attached to the nails for planting accuracy and was used to relocate seedlings after emergence. One seed was planted at each sample point ($n = 4320$) from 17–22 November 1988. The seeds were planted with awns intact at a depth equal to the length of the caryopsis.

Seedling emergence was determined 6–10 weeks later from 3 January–2 February 1989 by placing the planting grid on each transect and relocating every sample point. Seedling survival/mortality was determined before grazing on 21–27 March 1989. The height of each seedling was recorded as well as the height and species of its nearest neighbor. Neighbor species were categorized into 4 functional groups (*sensu* Goldberg and Werner 1983): 1) exotic grasses, 2) native grasses (all perennials), 3) exotic forbs, and 4) native forbs. The data were analyzed using the proportion ($S_i/(S_i + NS_i)$) where S_i is the number of seedlings with species i as the nearest neighbor. The number of planting locations with no seedling, but with species i as the nearest neighbor (NS_i) was used to weight the emergence data for each functional group. The proportion represents the actual number of seedlings observed in relation to the total number possible for a given nearest neighbor species. The proportional values were transformed (arcsine-square root) and analyzed using the SAS General Linear Model (Littell et al. 1991) to determine effect of nearest-neighbor functional group on *N. pulchra* seedling emergence.

To investigate the importance of seed mass on emergence and survival, we initiated Experiment 2 one year after Experiment 1 in the same experimental plots. *N. pulchra* seeds from the same bulk collection were separated into three dry-weight categories: small (≤ 0.0054 g), medium (≥ 0.0055 g and ≤ 0.0069 g), and large (≥ 0.0070 g). Twenty seeds of each size class were planted in transects paired with all Experiment 1 transects (4320 total seeds with 1440 in each size class) from 6–14 October 1989 (Fig. 1). Seedling emergence was determined 6–10 weeks later from 17 November–8 December 1989. For both experiments, surviving seedlings were surveyed 20–26 March 1990 and 2 June 1992.

In a mixed effects, split-plot model, analysis of variance (SAS GLM) was used to detect effects of burning and grazing treatments (main-plot factors) on seedling emergence, survival, and height. Topographic location (mound or intermound) was a sub-plot factor and seed size (Experiment 2 only) was used as a covariate. A split-split plot analysis was used to assess the effect of nearest-neighbor functional group (sub-sub-plot factor) on seedlings (Little and Hills 1978). A protected LSD procedure was performed for mean sepa-

TABLE 1. EMERGENCE (%) OF *NASSELLA PULCHRA* SEEDLINGS FROM 360 SEEDS PLANTED PER TREATMENT AND LOCATION AT JEPSON PRAIRIE, CALIFORNIA, FOR TWO EXPERIMENTS INITIATED IN 1988 AND 1989. Grazing treatments within the burned and unburned plots were wet-grazed (WG), dry-grazed (DG), and ungrazed (UG). Dates indicate time of survey of seedlings. Means within rows followed by different letters are significantly different at $P = 0.05$. Differences between mound and intermound means are significant at $P = 0.05$ (1989) and $P = 0.001$ (1990).

	Treatments						Mean
	Burned			Unburned			
	UG	WG	DG	UG	WG	DG	
Emergence (%)							
Experiment 1—March 1989							
Mound	32.8a	26.4ab	18.3bc	11.1c	16.9bc	11.4c	19.5b
Intermound	28.3ab	36.4a	22.8bc	15.0c	37.5a	22.8bc	27.1a
Experiment 2—March 1990							
Mound	20.8	30.1	10.3	5.6	11.9	15.6	15.8b
Intermound	34.4	33.1	17.8	9.9	19.4	26.4	23.4a

ration of pairwise comparisons. Each block was treated as a replicate and considered a random effect.

Before making comparisons between the two experiments, we compared the coefficients of variation for Experiments 1 and 2 with a variance ratio test (Lewontin 1966) to assess the degree of variability across years. Finding low variation and similar values, we examined differences between experiments with analysis of variance using treatment combination (burning and grazing) as the main-plot factor and topographic location as the sub-plot factor.

RESULTS

Seedling emergence and survival. *N. pulchra* emergence was rapid and fairly synchronous with 23.3% ($n = 1007$) of the seedlings in Experiment 1 and 19.6% ($n = 847$) of the seedlings in Experiment 2 emerging by March of the following spring (Table 1). Mortality in the first year after emergence was very high (Fig. 2). Survival of seedlings was 1.1% ($n = 48$) after one year (Experiment 1), 0.2% ($n = 19$) after two years (Experiment 2), and 0.1% ($n = 7$) after three years (Experiment 1). Twenty-six (1.4%) of the 1854 seedlings (0.3% of the 8640 seeds planted) from the 2 experiments survived until 1992. Annual rainfall totals were below average for the duration of the study (Fig. 3).

Treatment and topographic effects. We found significant location effects on emergence in both Experiment 1 ($P = 0.05$) and in Experiment 2 ($P = 0.004$). Consistently higher mean emergence rates were recorded on intermound sites for both planting dates regardless

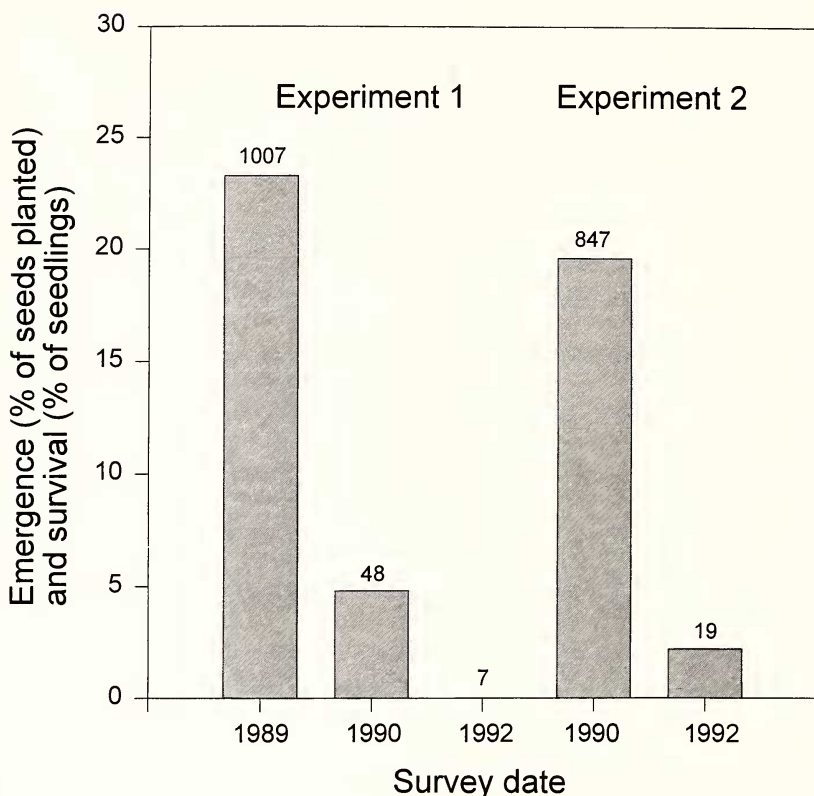


FIG. 2. Total emergence (% of seeds planted) and survival (% of seedlings) for all treatments of *Nassella pulchra* seedlings from 4320 seeds planted in 1988 and again in 1989 at jepson prairie, California. Values above each column represent numbers of seedlings recorded.

of treatment (Table 1). Seedlings were significantly taller on mound sites in Experiment 1 ($P = 0.003$) and Experiment 2 ($P = 0.0003$) (Table 2). However, for both emergence and height (Experiment 1), all significant differences between treatments disappeared by the second year.

Seedling emergence in Experiment 1 was greater in burned than in unburned plots ($P = 0.008$) and greater in wet-grazed than in ungrazed plots ($P = 0.02$). These effects were consistent across both mound and intermound locations (Table 1). A grazing by burning interaction ($P < 0.05$) was found in which dry-grazed and control plots had lower emergence than other treatments. In the second year, grazing was still a significant influence on emergence patterns ($P = 0.025$) with ungrazed plots having lower numbers of survivors. In

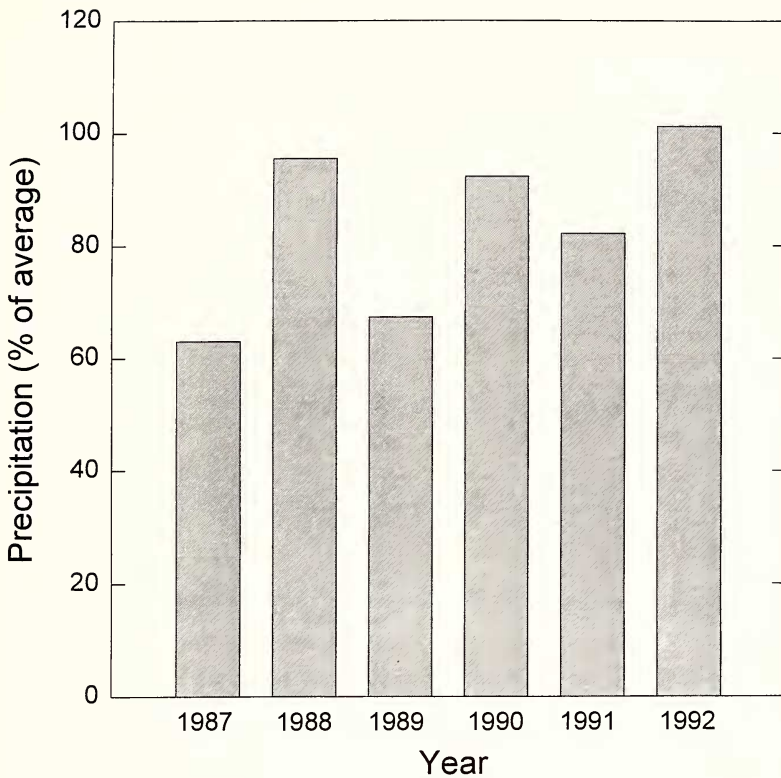


FIG. 3. Annual precipitation (% of normal) recorded at Davis, California for the years 1987–1992. The 100 year rainfall average is 43.6 cm: 7.62 cm (fall), 25.11 cm (winter), 10.41 cm (spring), and 0.46 cm (summer).

Experiment 2, no significant burning or grazing effects were found for emergence.

Experiment 1 seedlings were taller in ungrazed plots ($P = 0.04$) and in unburned plots ($P = 0.05$) while Experiment 2 seedlings showed no effect of burning or grazing on height. Topographic location of seedlings strongly influenced height in both experiments ($P = 0.003$ in Experiment 1, $P < 0.001$ in Experiment 2). Mean height of mound plants was greater than intermound plants for all treatments in both experiments.

In Experiment 2, a grazing by burning by location interaction effect was found for seedling height ($P < 0.02$) (Fig. 4). Within each treatment, mound seedlings were larger than intermound seedlings. The exception was ungrazed seedlings in unburned plots.

Nearest neighbor interactions. The plant functional group to which a nearest neighbor species belonged had no detectable effect

TABLE 2. HEIGHT (MM) OF *NASSELLA PULCHRA* SEEDLINGS FROM 360 SEEDS PLANTED PER TREATMENT AND LOCATION AT JEPSON PRAIRIE, CALIFORNIA, FOR TWO EXPERIMENTS INITIATED IN 1988 AND 1989. Grazing treatments within the burned and unburned plots were wet-grazed (WG), dry-grazed (DG), and ungrazed (UG). Dates indicate time of survey of seedlings. Means within rows followed by different letters are significantly different at $P = 0.001$. Differences between mound and intermound means are significant at $P = 0.003$ (1989) and $P = 0.001$ (1990). Empty data points indicate one-hundred percent mortality.

	Treatments						Mean	n
	Burned			Unburned				
	UG	WG	DG	UG	WG	DG		
	Height (mm)							
Experiment 1—March 1989								
Mound	22.7	19.1	19.7	28.0	16.8	23.8	21.7a	421
Intermound	16.6	17.8	14.7	23.5	18.1	17.9	18.1b	586
Experiment 2—March 1990								
Mound	53.1	36.8	42.3	41.7	49.8	43.6	44.7a	341
Intermound	39.3ab	32.1bc	33.7bc	48.3a	33.7bc	27.7c	34.8b	506
Experiment 1—March 1990								
Mound	79.3	61.0	30.5	—	51.5	26.0	56.0	15
Intermound	65.5	42.2	32.8	60.6	46.9	36.0	48.8	33

on seedling emergence. However, an interaction between time of grazing and plant functional group was noted. *N. pulchra* emergence next to native grasses (*N. pulchra*, *Distichlis spicata*, and *Melica californica*) decreased with dry-season grazing and increased when not grazed at all ($P = 0.04$) in comparison to other plant groups (Fig. 5).

Influence of seed weight on emergence and growth. Seed weight had no detectable effect on seedling emergence. Mean emergence was highest on mound sites for the medium weight category (40.6%), highest on intermound sites for the large mass category (36.0), and highest for intermound sites overall (59.7% of all seedlings) (Fig. 6). Emergence was greatest in the wet-grazed/burned treatment for all weight classes regardless of topographic location. The sole exception was for large seeds which had higher emergence in ungrazed/burned intermound sites. Seeds in ungrazed/unburned (control) plots showed the lowest emergence for all seed weight classes. However, since the power of the analysis of variance was less than 50%, this experimental design may have been ineffective for determining effects of seed weight on emergence and growth.

Year to year effects on seedlings. Treatment combination (burning and grazing) effects on emergence were found in Experiment

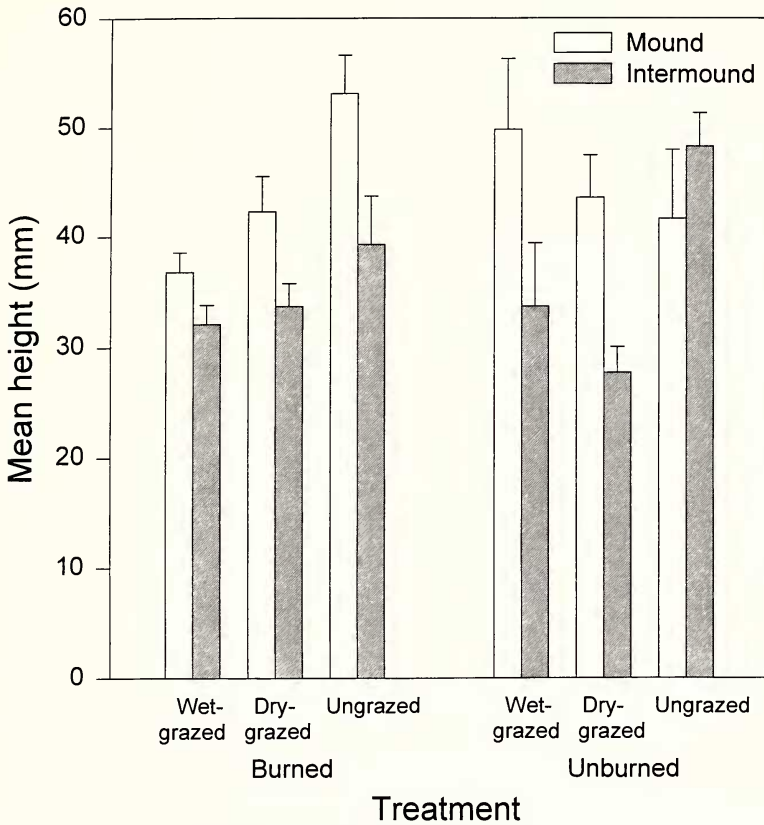


FIG. 4. Treatment interaction (grazing by burning by topographic location) ($P = 0.02$) for height (mm) of *Nassella pulchra* in 1989 plots at Jepson prairie, California. Standard error bars shown for each treatment mean.

1, but not in Experiment 2. The overall emergence means and coefficients of variation were not different for the 2 experiments when compared with a variance ratio test (Experiment 1: mean = 23.3, CV = 45.57; Experiment 2: mean = 19.8, CV = 50.43).

The mean height of Experiment 2 seedlings was significantly greater ($P = 0.001$) than Experiment 1 seedlings in both topographic locations in the first growing season (Fig. 7). A significant year by location interaction ($P = 0.02$) was found as the difference between mound and intermound plants increased from Experiment 1 to Experiment 2 (Fig. 7). However, despite the result of the variance ratio test regarding emergence, these results indicate that conditions were significantly different between years which brings into question the validity of statistical comparisons between these experiments.

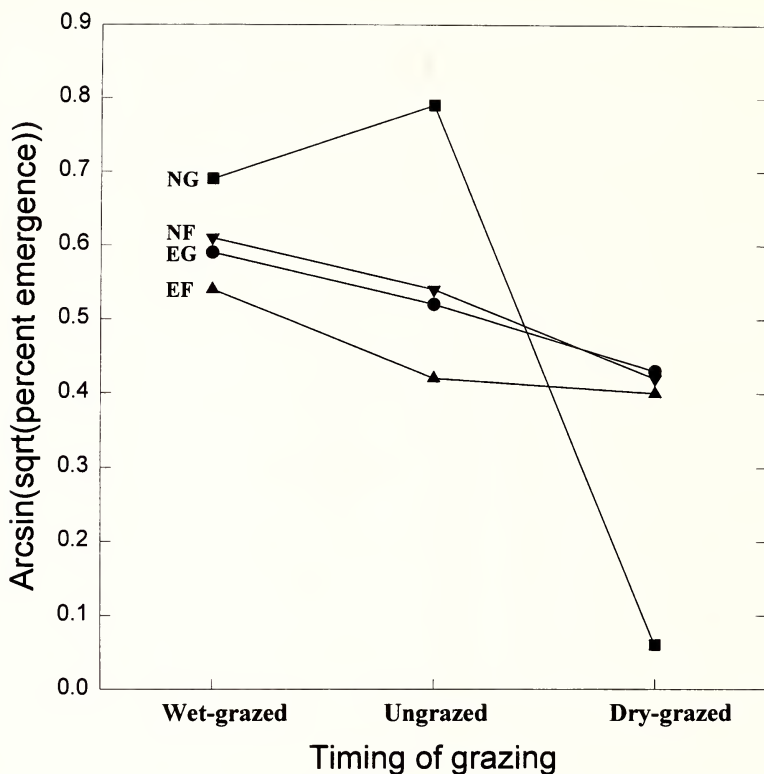


FIG. 5. Emergence of *Nassella pulchra* seedlings next to four functional plant groups in 1988 Plots at Jepson prairie, California. Values are arcsine square-root transformations of the proportion of the number of seedlings to the number of possible sample locations with a particular nearest neighbor. Nearest neighbor functional groups are 1) exotic grasses (EG), 2) native grasses (NG), 3) exotic forbs (EF), and 4) native forbs (NF).

DISCUSSION

In the first experiment, late-summer fire and short-duration grazing prior to planting strongly affected the rates of emergence of *Nassella pulchra* seedlings. Treatment combinations that included burning or wet-season grazing had the greatest positive effect on emergence although the degree was influenced by the topographic location. The effect of burning was more pronounced than grazing. In the first season following the burn, plots that were burned but not grazed had significantly higher emergence than plots that were grazed but not burned. Litter removal and thus the potential for altering the annual grass seed bank was greater with burning than with grazing. Spring grazing (i.e., defoliation of annual grasses dur-

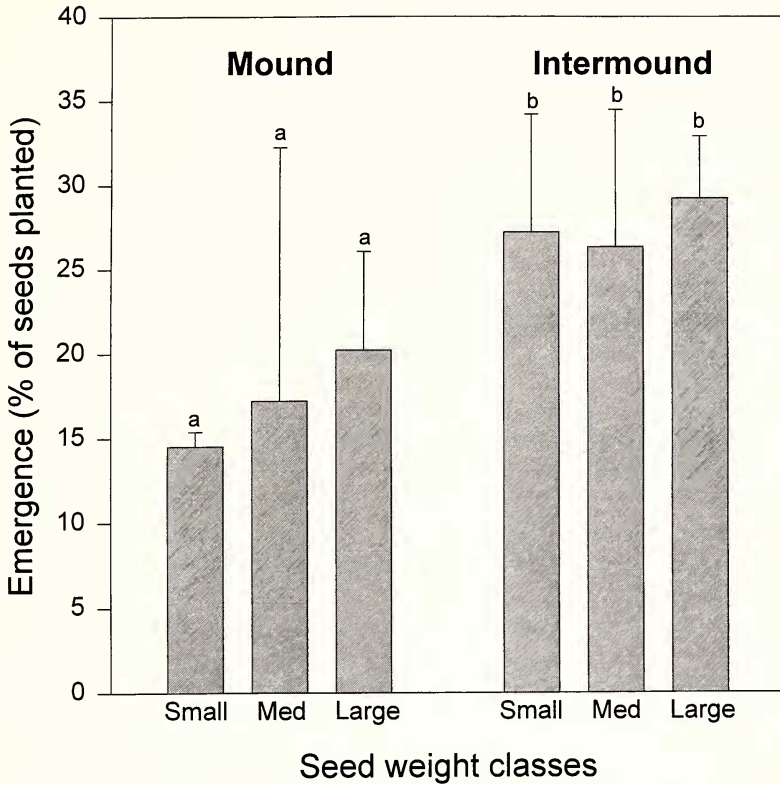


FIG. 6 Emergence (%) of *Nassella pulchra* seedlings of three seed weight categories (720 seeds per weight class) at Jepson prairie, California. Columns with different letters are different at $P = 0.001$. Standard error bars shown for each column.

ing their reproductive phase) had greater potential than summer grazing for reducing annual grass inputs to the soil seed bank.

Although fire is the most effective method for eliminating surface litter, its effect on community composition in California grasslands is short-lived and lasts 1–3 years (Hervey 1949; Cook 1979; Parsons and Stohlgren 1989). The second experiment, initiated one year after the prescribed burn, did not produce significant treatment effects on seedling emergence. Although the first experiment indicated that burning had a stronger effect than grazing, we suspect that time since burning was an important aspect of the burning effect (i.e., the period of enhanced germination appeared to be restricted to the first growing season after a fire.) Rapid reestablishment of surface litter by annual species could explain why a treatment effect was not found in the second experiment. The lack of statistical significance in the second experiment was not from a lack of statistical

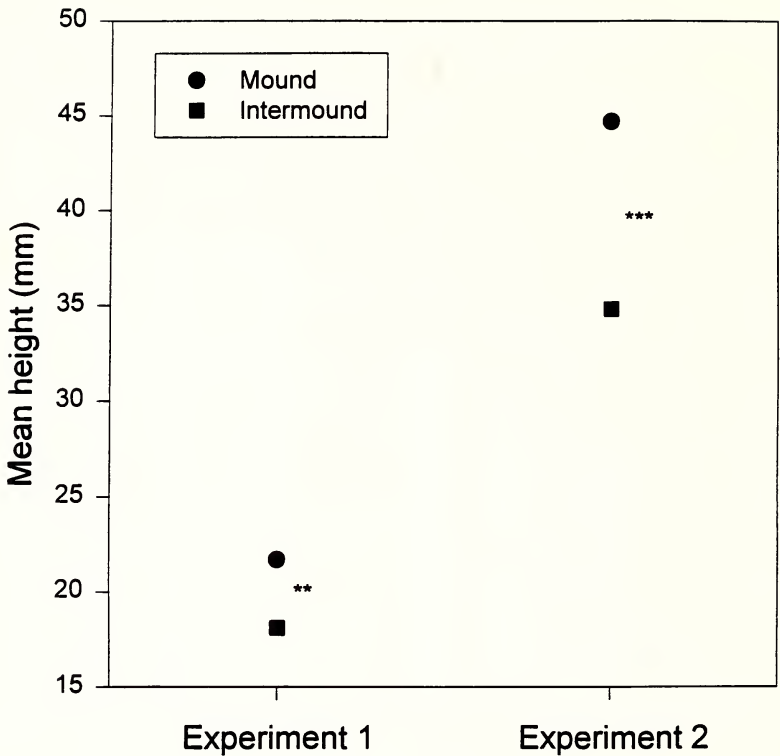


FIG. 7. Mean height (mm) of *Nassella pulchra* seedlings in mound and intermound locations at Jepson prairie, California. Experiment 1 was planted immediately following a prescribed burn and Experiment 2 was planted one year later. Significant influence of location on plant height is indicated by** ($P < 0.01$) and by*** ($P < 0.001$).

power, but from the amount of variance within the data. The error term used to test the main effects of burning and grazing in Experiment 1 was relatively small and in Experiment 2 it was relatively large and resulted in no significant effect of treatments.

Both experiments suggest that topographic location was a stronger determinant of emergence than either burning or grazing. The higher mean emergence for all treatments (except ungrazed-burned in Experiment 1) in intermound areas may reflect lower competition for light because of the lower biomass and canopy development of the intermound vegetation. In early spring, when moisture is not limiting, primary competition is for light (Grubb 1992) and the intermound would be more suitable for seedlings than the mound because of greater light penetration to the soil surface.

Grass growth rates are inversely associated with light availability (Weaver and Rowland 1952; Facelli and Pickett 1991) which is, in

turn, a function of canopy cover and stand density. Seedling height prior to grazing was a useful measurement for assessing the potential effectiveness of treatments in reducing canopy development and light competition with neighbors. A seedling in the California grassland may have several hundred to several thousand neighboring individuals of many species within a radius of 10 cm (Major and Pyott 1966; Young et al. 1981). The neighbors compete for soil moisture and available light and create a canopy as the growing season progresses. Thus, the species composition of the immediate neighborhood may be critical to seedling emergence. However, in a community as densely populated as the annual grassland, the concept of a single individual of any species having a profound effect on its nearest neighbor may be questionable (Fowler 1984). The observation in this study of the significant effects from native perennial grasses as nearest neighbors (and not from other functional groups) is therefore difficult to interpret. We can only suggest that the presence of an established perennial grass exerts a substantial influence on seedling vigor. This influence would likely be related to below-ground resource acquisition since our treatments manipulated above-ground biomass variables only.

We did not find a strong association between seed weight and emergence or survival. Although a weak relationship ($P = 0.2$) was noted between seed size and seedling height, the tallest seedlings occurred in plots exhibiting the greatest neighborhood canopy development. These results suggest an apparent, canopy-induced, etiolation effect (Weaver and Rowland 1952; Knapp and Seastedt 1986) and an interaction between treatments and topographic location. Therefore, any contribution made by seed weight to growth, competitive ability, or survival will vary in different microhabitats.

As has been noted, rates of emergence were different across treatments in both mound and intermound locations in Experiment 1, but not in Experiment 2. Conversely, seedling height was not strongly affected by treatments in Experiment 1, but was affected by treatments in the intermound in Experiment 2. Although the role of climatic variables, especially rainfall patterns, for influencing emergence and growth should not be discounted, these results suggest a diminution after one year of the effect of burning on emergence. If burning effects are short-term, the effects of the grazing treatment would be expected to be more apparent in Experiment 2. However, the significant differences in mean height between treatments in intermound, but not mound, plots seen in Experiment 2 suggest that grazing was ineffective in reducing the annual biomass on mounds. A significant grazing by location interaction term in the second year of Experiment 1 ($P < 0.04$) and our observation that sheep prefer to graze intermound areas support these results. Therefore, since our

assumption of no difference between years appeared invalid, we chose not to use the between-years statistical comparisons.

Survival after 3 to 4 growing seasons was less than 1% regardless of time since the burning treatment and despite continuation of the annual grazing treatment. We were surprised so few seedlings survived to the end of the second growing season. However, high seedling mortality in grasslands is a predictable outcome (Cook 1979; Bartolome and Gemmill 1981) and negative effects of grazing on perennial grass seedlings have been reported (Cook 1979; Salihi and Norton 1987).

The high rate of mortality at the seedling stage reflects the intensity of resource competition within the grassland community. The delayed phenological development of perennial bunchgrasses in comparison to annual grasses may put them at a competitive disadvantage (Bartolome and Gemmill 1981; Jackson and Roy 1986). Early emergence allows early access to resources and the opportunity to gain a relative competitive advantage (Ross and Harper 1972). Treatments that reduce or delay growth of the canopy-forming annual species therefore create improved conditions for establishment of perennial grasses.

Surveys of seedlings before and after the first and before the second growing season indicated that virtually all mortality occurred during or just before the summer months. Ongoing research has indicated that the vigor of the seedlings prior to the dry summer months may be an important factor for predicting subsequent survival (Dyer in preparation). The vigor of the seedling is strongly influenced by the growing environment in the preceding months. In particular, the amount of light penetrating the canopy to the seedling level may be a critical factor (Weaver and Rowland 1952; Knapp and Seastedt 1986).

The severity of post-emergence resource competition and its impact on seedling survival (low seedling survival was observed even when buildup of annual vegetation was reduced by management) was well illustrated in this study. It is possible that below-average rainfall may have intensified the severity of growing conditions. A shorter-than-average growing season and early depletion of soil moisture coupled with shallow soils may have influenced the final numbers of survivors. However, current research indicates that early-season light availability may be even more critical for *N. pulchra* seedling survival than late-season moisture availability (Dyer, in prep.). In fact, other recent work indicates that years of below-average rainfall, by reducing annual grass development, may potentially encourage pulses of recruitment of *N. pulchra* in some areas (F. T. Griggs unpublished data).

CONCLUSIONS

The use of prescribed burning and short-duration grazing for enhancing seedling recruitment into *Nassella pulchra* populations has not been supported by this study. Although emergence rates of seedlings in burned and grazed treatments appeared favorable initially, the probability of reaching a mature stage was low for a bunchgrass seedling at Jepson Prairie during the period of this study. The treatments applied were expected to alter resource availability for seedlings (e.g., the decreased biomass of annuals would result in increased resource availability for perennial seedlings.) The low overall survival indicates a failure of the treatments to modify environmental conditions sufficiently to increase *N. pulchra* seedling survival. The extended period of below-average annual rainfall and the shallow soils of Jepson Prairie may have contributed to the low survival.

The factors controlling emergence and survival of *N. pulchra* are probably more complex and integrated than can be tested by the broad treatments implemented in this study. Other environmental factors which may complicate the issue and which should be investigated in future work include a) soil depth, b) timing of and amount of annual precipitation, and c) timing of treatments within a season and throughout the year rather than intensity or frequency of treatments. We also acknowledge that recruitment likely occurs in pulses and that a "good" year for recruitment may require the simultaneous occurrence of several favorable environmental conditions (Fowler 1986). Identification of essential environmental conditions for emergence and survival of *N. pulchra* seedlings will continue to be a research goal. However, the design of experiments that simultaneously manipulate the many environmental variables involved may ultimately prove intractable.

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ANNOUNCEMENT

THE RUPERT BARNEBY AWARD

The New York Botanical Garden is pleased to announce that Gwilym Lewis of the Royal Botanic Gardens, Kew, is the recipient of the 1995 Rupert Barneby Award. Mr Lewis will be working on the legumes of Ecuador.

The New York Botanical Garden also invites applications for the 1996 Rupert Barneby Award. The award of \$1000.00 is to assist researchers to visit The New York Botanical Garden to study the rich collection of Leguminosae. Anyone interested in applying for the award should submit their curriculum vitae and a detailed letter describing the project for which the award is sought. Travel to NYBG should be planned for sometime in 1997. The letter should be addressed to Dr. James L. Luteyn, Institute of Systematic Botany, The New York Botanical Garden, Bronx, NY 10458-5126 USA, and received no later than December 1, 1996. Announcement of the recipient will be made by December 15th. Anyone interested in making a contribution to THE RUPERT BARNEBY FUND IN LEGUME SYSTEMATICS, which supports this award, may send their check, payable to The New York Botanical Garden, to Dr. Luteyn.